

Integrated online temperature monitoring and traceability in a cold meat chain using EPCIS

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Abstract A pilot test was conducted to evaluate the functionality of an EPCIS based online system for time-temperature monitoring and documenting traceability in a cold meat chain. The test was performed during transportation of chilled lamb products. The RFID based temperature sensors were used to record temperature of the product and ambient temperature inside the container at 10 min time intervals during transportation between processing plant and a distribution terminal 800 km away. The sensors communicated with the GSM-based unit installed in the truck and transmitted the data to an EPCIS based system which was accessible through a web interface. The temperature information was recorded as EPCIS events. The results of the application of EPCIS for online temperature monitoring are presented in this paper.

Keywords online temperature monitoring, EPCIS, cold chain, traceability

1 Introduction

Transportation and logistics are integral parts of fresh food supply chains and the transportation segment has the greatest risk associated with it due to multi-party involvement, mishandling of information and the length of the segment. These complexities can lead to product spoilage, losses and change in shelf life of food. The design and management of food supply chains is a complicated task because of an intrinsic focus on product quality (Luning and Marcelis, 2006). Consumers expect that the food they buy in retail stores must be of good quality and adequate shelf life (Smith and Sparks, 2004). Several studies have also been conducted on the amount of food waste in US and Europe over the last few decades. Most of these studies however, focus on food waste from households and only a few take the retail and wholesale sector into consideration (Stenmarck et al., 2011).

Fresh food products need to be stored and transported in a temperature controlled environment to maintain and even improve quality (in case of ripening fruits). There are a number of difficulties in managing temperature-controlled food supply chain networks such as the short shelf life which puts additional requirements on speed and reliability of logistics systems and requires specialized transportation and storage equipment. Food degradation is related to environmental conditions (such as temperature and humidity), intrinsic properties (such as microbial contamination, composition, etc.) and the time that food products are exposed to

these conditions (Van der Vorst et al., 2007). Several studies have been conducted on food quality decay modeling and time-temperature impact of the quality throughout the distribution (Sloof et al., 1996; Taoukis and Labuza, 1999; Schouten et al., 2006; Bobelyn et al., 2006).

1.1 Electronic Traceability

Automated traceability is based on electronic data capture and exchange. Electronic data capture can be optical or radio-wave systems, for example, barcodes and RFID technology. The interest in these systems for traceability has been increasing recently. RFID tags essentially contain Electronic Product Codes (EPC) generation 2 (EPCglobal, 2007). Most of the research in this field presents traceability solutions where only the product packaging is tracked through the supply chains but fail to address the internal traceability issues linked to the production events within a food facility. Regattieri et al. (2007) presented the application of an RFID system integrated with alphanumeric code to trace Parmigiano Reggiano cheese through the complete supply chain. Shanahan et al. (2009) proposed the use of RFID for the identification of individual cattle and biometric identifiers for verification of cattle identity. They also proposed a data structure for RFID tags and a middleware to convert animal identification data to the EPC data structure. Bottani and Rizzi (2008) studied the impact of RFID technology and EPC system on the main processes of the fast moving consumer goods supply chain that composed of manufacturers, distributors and retailers. The outcomes of their study provided economical justifications for implementation of RFID and EPC in fast moving consumer goods supply chains.

1.2 Electronic Product Code Information Services (EPCIS)

EPC provides a method for unique identification of all items in a supply chain. The use of EPC also makes it possible to register internal and external events electronically that are related to the movement of tagged items. The standard for using RFID is based on EPCglobal standard. EPCIS is an EPCglobal standard designed to enable EPC-related data sharing within and across enterprises (EPCIS Standard, 2007). Automated traceability systems have existed in Nordic countries for several years (Storøy and Olsen, 2007) but EPCIS makes the data capture and exchange electronic thus making EPCIS an applicable standard. There are two kinds of EPCIS data, event data and master data. Event data is created in the process of carrying out business processes, and is captured through the EPCIS Capture Interface and made available for query through the EPCIS Query Interfaces. Master data is additional data that provides the necessary context for interpreting the event data. It is available for query through the EPCIS Query Control Interface. The EPCIS events cover normal logistic and stock control processes by the use of the Event classes: ObjectEvent, AggregationEvent, QuantityEvent and TransactionEvent. The basic chain traceability requirements with respect to managing and recording transactions between different business actors are directly covered by EPCIS Events. The use of EPCIS and RFID is limited to tracking the product packages between stakeholders but the additional food product transformations (or transitions) that include process and quality

parameters are not covered under the basic EPCIS specification. The structure of the EPCIS architecture is shown in Figure 1.

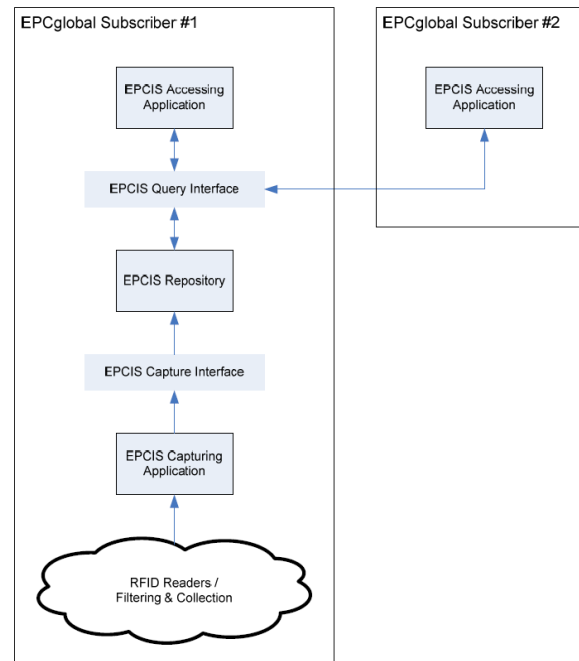


Fig. 1 Overview of EPCIS architecture (EPCglobal, 2007)

1.3 Cold chain time-temperature monitoring

In case of perishable products, precise temperature monitoring in the supply chain especially during the transportation process is very important to ensure product quality and safety. Current temperature monitoring systems used in the cold chains are usually strip chart recorders or temperature data loggers which are not automated and require manual inspection. Continuous temperature monitoring is not possible with these methods. Traceability and time-temperature in food logistics is often handled independently. Most common solution is to use conventional paper labels for traceability information with a strip chart recorder placed inside two or three marked boxes per shipment to monitor the temperature. More recently, several solutions for monitoring temperature based on traceability systems using RFID tags with integrated temperature sensors have been developed (Ogasawara and Yamasaki, 2006; Jedermann and Lang, 2007, Thakur et al., 2011). However, the information from such RFID tags with temperature sensors cannot be retrieved in real-time while the food product is in transit.

The objective of this work was to test an online system for temperature monitoring and traceability in a cold meat chain. The goal was to test the EPCIS system and

RFID technology for online monitoring of time-temperature and traceability of chilled lamb products during transportation.

2 Materials and Methods

Chilled legs of lamb were used as the test products in this study. The products were transported in a refrigerated truck from the processing plant to a distribution terminal 800 km away.

2.1 RFID based temperature sensors

EPCglobal UHF Class 1 Generation 2 RFID tags with integrated temperature sensors as shown in Figure 2 were used in this study. Sensors were used for both ambient temperature in the truck during transportation as well as the product temperature. Nine RFID tags with internal temperature sensors were used for recording ambient temperature and four tags with external temperature probes were used for recording product's core temperature.

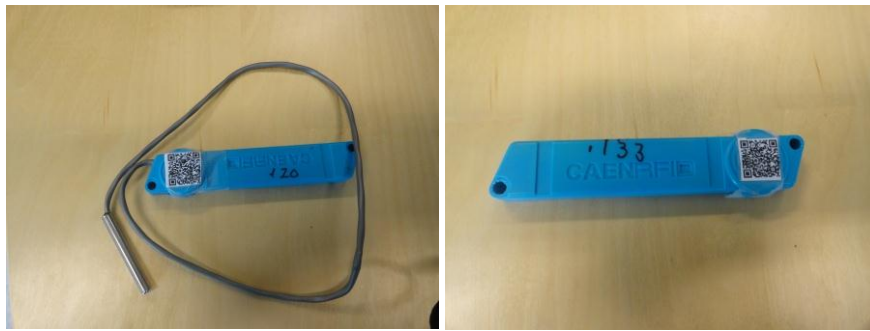


Fig. 2 RFID based temperature sensors with external and internal sensors respectively

2.2 Communication system

RFID and GPS antennas and a GSM/GPRS based communication unit were used to read the temperature data and transmit it online to the EPCIS based online temperature monitoring system. The RFID antenna and communication unit is shown in Figure 3. The read zone of the RFID antenna is 1.5 m wide and 6 m long. The communication unit is connected to a 12 V power outlet.

2.3 Pilot test Set-Up

Figure 4 below shows the states and events in the lamb processing. The events where the RFID tags and the communication system were installed can be seen. The main focus in this test was the transportation event where the temperature data was logged and communicated online. The figure also shows the placement of the RFID tags in the truck and the product. Placement of RFID tags with external temperature probes in the product during the packing event and the

communication unit is shown in Figure 5. The final test was conducted on 23rd November, 2011 in Norway during the transport of lamb legs from the processing facility to the distribution terminal. All sensors were programmed to record temperature every 10 minutes during transportation. The reader was intended to capture each tag's unique RFID number, as well as temperature data. The solution was designed so that whenever the reader captured data from the tags, the communication unit forwarded that information, along with the truck's GPS coordinates, to the EPCIS system on a standalone back-end system, via a GSM cellular radio, transmitting through the truck's fiberglass walls.



Fig. 3 RFID antenna and communication unit

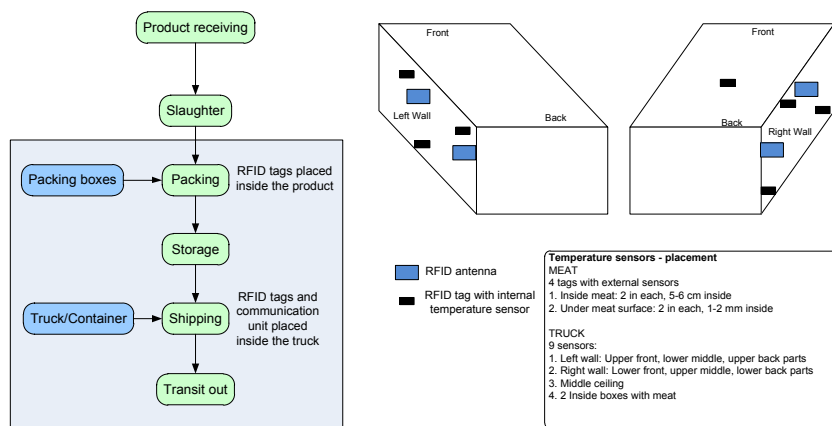


Fig. 4 States and events in lamb processing; and placement of RFID temperature sensors

3 Results

3.1 EPCIS - Web based monitoring

The Web-based monitoring system developed by HRAFN was used for real-time temperature monitoring during the transportation of chilled lamb product. The RFID tags with integrated temperature sensors communicated with the main unit

installed in the truck and transmitted the data to an EPCIS based system which was accessible through a web interface. The temperature data was linked to a specific event with the parameters shown in Table 1. The online geo-location for each RFID tag could be accessed on the map as shown in Figure 6. Figure 7 shows the real-time temperature data. The historical data for 36 hours could be accessed through the web-interface in a graphical format as shown in the Figure.



Fig. 5 Placement of RFID sensors inside the product and the equipment setup

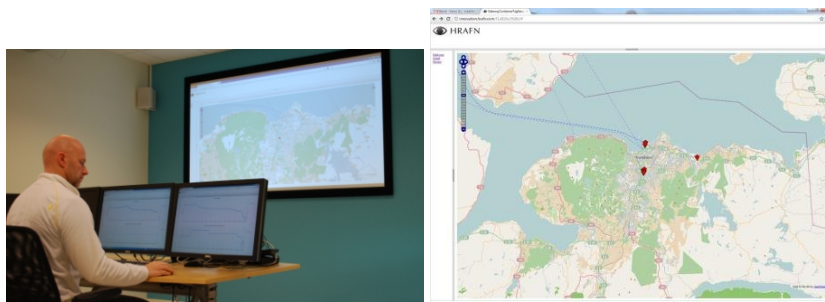


Fig. 6 Web interface for monitoring location and temperature

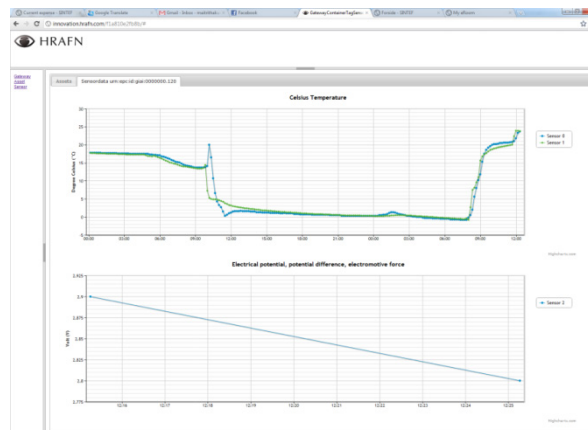


Fig. 7 Real-time temperature data available from the web interface

3.2 EPCIS temperature events

An EPCIS event was created when temperature was read (every 10 minutes) and linked to each uniquely identified tag. The *business step* was defined as *temptracking* and *disposition* as *in_transit* for the temperature logging during the transportation process. An example of the XML code generated for an Object Event where temperature is recorded is shown below:

```
<EPCISBody>
<EventList>
<ObjectEvent>
<eventTime>2011-11-23T12:21</eventTime>
<epcList>
<epc>urn:epc:id:giai:0000000.121</epc>
</epcList>
<action>OBSERVE</action>
<bizStep> urn:hrafn:temperature:bizstep:temptracking </bizStep>
<disposition> urn:epcglobal:cbv:disposition:in_transit </disposition>
<readPoint>
<id> urn:hrafn:readpoint:licenceplate:SINTEF </id>
</readPoint>
<bizLocation>
<id> urn:hrafn:readpoint:licenceplate:SINTEF</id>
</bizLocation>
<temp1>0.3 </temp1>
</ObjectEvent>
</EventList>
</EPCISBody>
```

4 Discussion

Decision making in logistics and transportation planning of fresh food is characterized by product quality deterioration during transport in addition to the inherent properties of all supply chains in general. The amount of food wasted due to quality deterioration is particularly important. The functionality of an online system for monitoring time-temperature linked to EPCIS events is presented in this paper. The hardware prototype was premature for industrial implementation, but provided enough information to conclude that the EPCIS was applicable for "linking" temperature information to the traceable units and events. An online temperature monitoring system like this could have a potential to reduce food wasted due to quality deterioration without increasing use of human resources for maintaining temperature control or transfer of information.

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